

ANIMATION OF FINITE ELEMENT MODELS AND RESULTS

Robert R. Lipman

David Taylor Research Center
Computational Signatures and Structures Branch (Code 1282)
Bethesda, Maryland 20084-5000

SUMMARY

Several years ago, the phrase 'visualization in scientific computing' (ref. 1) was coined for what we used to call computer graphics. Although computer graphics is part of visualization, visualization encompasses computer graphics hardware and software, network communications, user interfaces, computer-aided-design, and more. The purpose of visualization is to provide insight into the engineer's models and calculations. Animation of finite element models and results is a visualization process that can provide the insight.

The paper is not intended to be a complete review of computer hardware and software that can be used for animation of finite element model and results, but is instead a demonstration of the benefits of visualization using selected hardware and software. Opinions expressed are solely those of the author and are not those of the David Taylor Research Center, the Navy, or the Department of Defense. Good reviews of visualization hardware and software can be found in the following journals: Computer Graphics World, Supercomputing Review, IEEE Computer Graphics and Applications, and CAE Computer-Aided Engineering. A videotape showing visualization and animation of finite element models and results is an integral part of this paper although it is not included in the proceedings.

INTRODUCTION

Visualization and animation give an engineer insight into his finite element model and results. Wire-frame plots of a finite element mesh do not convey the sense that a 'real' structure has been modeled. We do not live in a wire-frame world. We live in a world of color, light, shading, and perspective. A beam is not a line between two points. A beam has a web and a flange of substantial size and cross-section. The transient motion of a structure cannot be determined from static plots at selected time steps or plots of the response of a node versus time. Visualization and animation can be used to show an engineer the realistic configuration and response of a structure.

The earliest animations of finite element analysis results were made by painstakingly recording a sequence of static plots on film. Some of the first computer animations of finite element analysis results were made on Evans & Sutherland graphics hardware (ref. 2). Today, with the price/performance of computer graphics hardware so low and visualization software packages becoming more mature, finite element model visualization and animation is now a desktop tool.

HARDWARE

It seems that computer workstation vendors are announcing faster and less expensive hardware almost every day. Current Cray X-MP supercomputer computational speeds should be available in desktop computer workstations in 1-2 years. By the time this paper is presented, the 1-2 year time frame may have been reduced from years to months. The cost of memory and hard disk storage is also falling.

As important as raw computational power is to animation and visualization, graphics speed is equally important. Graphics speed, usually quoted in polygons per second, is not increasing as fast as computational speed. Rather, the cost of current graphics power is getting less expensive. Current peak graphics speeds of 200,000 polygons per second can be found on the top-of-the-line graphics workstations. The user must beware of the type of polygon that the vendor uses when quoting graphics speed. Quotes of one million polygons per second are usually for highly optimized meshes of triangles without light-source shading. For animation of finite element models, the graphics speed for independent quadrilateral polygons is more relevant.

When computation and visualization take place in a distributed environment, communications speed between the client and server is another important issue. Today, animations of finite element analysis results are typically done in a batch mode. The analysis is done on a large mainframe or supercomputer and the results are sent to a workstation to be used with visualization software. In the future, the two processes of analysis and visualization will be more tightly coupled where the analysis and visualization are being computed concurrently. For this scenario to take place, much higher network communications speed between the computational server and visualization server will be necessary than current local- and wide-area networks provide.

Finally, animation sequences have to be recorded to videotape. There are two methods for recording computer graphics animations on videotape: real-time and frame-by-frame. For real-time recording, the computer graphics display is converted, in real-time, to a television signal suitable for recording on videotape and being displayed on a regular television monitor. Therefore, whatever is being displayed on the computer graphics display can be recorded to videotape. If the graphics speed is fast enough to animate a finite element model in real-time, then this process is sufficient.

With graphics hardware that is not fast enough and with visualization software that has a rendering capability, then frame-by-frame recording can be used. The visualization software renders individual images that are recorded one-by-one on videotape. The result is a continuous animation sequence. Frame-by-frame recording also produces higher quality animations and renderings than real-time animation.

SOFTWARE

Visualization software packages can be separated into three categories: general-purpose, modular, and application specific. The types of data that the packages can visualize are usually either structured or unstructured grids. A structured grid is typical for finite-difference applications such as computational fluid dynamics. A finite element mesh is an example of an unstructured grid. Many of the general-purpose visualization packages (PV-Wave, Spyglass, Data Visualizer) are very good with structured grids and less useful for finite element applications. There are also several application specific visualization packages (Fieldview, Fast, Plot3D) that

can be used with only structured grids. The modular visualization packages (AVS, Iris Explorer, apE) allow users to write their own applications specific software modules to be integrated with the visualization software.

There are few choices for application-specific visualization packages for finite element analysis animation. The popular finite element pre and postprocessors (Patran, I-DEAS) have animation capabilities, but are not oriented to the visualization process and to recording videotapes. FOTO (ref. 3) is a data visualization software package geared towards finite element models and animation. FOTO was used to make the videotape that is part of this paper. FOTO is easy to interface with analysis codes; is user-definable menu driven; has many visualization types including: color, displacement, contour lines, vectors, transparency, and culling operators; and has a tightly coupled videotape system.

There are also free visualization software packages available from the national supercomputer centers. Because they are free, the source code is provided allowing the user to tailor the code to his application. However, because they are free, the user will not get the same type of support or updates to the software that a commercially available package would provide.

THE FUTURE

What is currently possible for finite element animation and visualization is not the final product, but only a step towards a more interactive, dynamic environment for doing analysis and visualization. In the future, analysis and visualization will occur concurrently in near real-time and the engineer will have the capability to interact with the analysis by changing the finite element model as the computations are taking place to explore new configurations of the model.

REFERENCES

1. McCormick, B.H., T.A. DeFanti, and M.D. Brown; Editors, "Visualization in Scientific Computing," ACM SIGGRAPH, November 1987.
2. Lipman, R.R., "Computer Animation of Modal and Transient Vibrations," in: *Proceedings of 15th NASTRAN Users' Colloquium*, 4-8 May 1987, Kansas City, Mo., National Aeronautics and Space Administration, NASA CP-2481, pp. 111-117, Washington, D.C. (1987).
3. "FOTO User Manual," Cognivision, Inc., Westford, MA, 1992.